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Our project focuses on developing multimedia systems to support human learning, based on cognitive principles and guidelines from cognitive science. The question is not so much whether multimedia makes a difference, but rather how can it best be deployed to make a difference? Specifically, what combinations of media and methods of interaction are most effective for learning, and why? Cognitive science has made significant advances in understanding human learning and training issues. Based on these advances, we can make strong hypotheses about how to construct effective interactive multimedia learning environments. We are using these hypotheses as the basis for a principled approach to the development of multimedia training systems and, in turn, further advance our understanding of learning and of media through careful assessment of the systems. In our initial investigations summarized here, our focus has been primarily on whether encouraging learners to interact in different ways with the system affects their learning, learning rate, and or transfer to new problems.

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Using Cognitive Principles to Design Multimedia Training Environments to Support Learning

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Our project focuses on developing multimedia systems to support human learning, based on cognitive principles and guidelines from cognitive science. The question is not so much whether multimedia makes a difference, but rather how can it best be deployed to make a difference? Specifically, what combinations of media and methods of interaction are most effective for learning, and why? Cognitive science has made significant advances in understanding human learning and training issues. Based on these advances, we can make strong hypotheses about how to construct effective interactive multimedia learning environments. We are using these hypotheses as the basis for a principled approach to the development of multimedia training systems and, in turn, further advance our understanding of learning and of media through careful assessment of the systems. In our initial investigations summarized here, our focus has been primarily on whether encouraging learners to interact in different ways with the system affects their learning, learning rate, and or transfer to new problems.

May 15, 1995 - November 14, 1995

Important Findings and Problems Encountered

We have conducted two initial studies to examine the effects of cognitive media types and self-explanations on learning in multimedia systems. One experiment was in the domain of chemistry (determining molecular shapes) and the other was in the domain of computer graph theory. While the experiments are described in more detail below, the major findings are that the type of learning orientation induced in students when interacting with different versions of the systems leads to different browsing (through the system) patterns but does not appear to lead to differences in test performance. However, these initial findings must be tempered by the observation that these studies were designed to debug the materials as much as to debug and learn about the consequences of various manipulations to the

multimedia learning environments.

Changes in Overall Plan and Personnel

None.

Experiments

Chemistry

In an attempt to test some of our ideas about cognitive media types and self-explanation, we collaborated with a Chemistry professor at Emory University in the design of instructional software for teaching students how to solve problems involving the determination of molecular shape. This topic is particularly difficult for introductory Chemistry students so the potential benefits in this domain are considerable.

The software, which we called ChemLab, is based on an outline of the problem solution procedure developed by our domain expert (the Chemistry professor). The steps in the procedure for determining molecular shape were laid out in a map that students could follow to arrive at a solution. Each step contained four cognitive media types that learners could utilize:

1. Definitions. Key concepts relevant to this step and the operations required at this step of the procedure.
2. Examples. Concrete examples of this step in the procedure (or the key concept in the step).
3. Worked problems. This was generally a "before and after" presentation in which the students saw a partial solution before the step was performed and then after it was performed. Explanations for the operations were also present.
4. Problem sets. This is similar to a worked problem but provides an opportunity to test one's knowledge. The screen presents a "before the step" situation and asks the learner to execute the step in their head or on scratch paper. The learner can request that the solution then be shown to verify their solution.

Because this particular domain is very visual, ChemLab makes extensive use of figures along with the text within all of the cognitive media types. However, use of other physical media types were limited. The semi-public computer cluster environment made it difficult for us to use sound, and time constraints made construction of animations impossible. Future versions of ChemLab will use animation to help illustrate the more dynamic content, though the use of sound is still an unresolved issue.

The participants in the ChemLab experiment were approximately 80 undergraduates who enrolled in an introductory Chemistry course at Emory university, who participated in the experiment for extra-credit. Participants were given paper "cheat sheets" to help them navigate the ChemLab software. The software itself was run on Macintosh Centris personal computers and developed in Apple's HyperCard (version 2.3).

All participants had access to the same instructional material in the software and were given the same post-test after using the software. The post-test was a short quiz designed by the regular chemistry professor for the course.

The ChemLab software was presented to participants in one of four conditions:

1. Passive watching. In this condition, participants were given access to the ChemLab instructional material and little guidance. They were instructed to "work through the materials until you are pretty sure you are prepared to solve some problems." This is the control condition to which others can be compared.

2. Directed watching. In this condition, we wanted to give the participants some learning goals while browsing through ChemLab. Thus, participants were given a series of questions to answer to help guide their browsing. These questions concerned different aspects: some were oriented towards the procedure (e.g. "how do you do X?" or "what do you do after step Y?"), some were oriented toward specific content (e.g. "what's the chemical formula for Hydrazine?"), some were definitions, and the rest were miscellaneous things that participants would have to find.

3. Problem solving. Participants in this condition could not only browse ChemLab, but were asked to solve two specific molecular shape problems. As they were doing so, they were allowed to use ChemLab as a resource to help them solve the problems (including a feature called "The Molecule Construction Kit"). This condition was included to encourage participants to spontaneously generate learning goals directly relevant to solving real problems.

4. Problem solving with prompted self-explanations. This condition was identical to condition 3 with one addition: at various points while participants solved the problems, they were prompted to explain what they were doing and why. It was hoped that this manipulation would increase reflection and self-explanation.

Participants were run over five consecutive school days spanning seven calendar days. They were run in a semi-public Macintosh cluster on the Emory campus in groups of up to six.

After filling out the consent form, participants logged into the ChemLab environment, which handled condition assignment and data collection. While browsing ChemLab, participants' mouse clicks were logged and time stamped. After participants finished working with ChemLab, they were given the post-test.

While all of the data have been collected, the log files have not yet been extensively analyzed, due to their complexity. However, some preliminary results are available. First, there were no reliable group differences in the overall post-test scores–analyses for individual questions on the post-test are still pending. On the other hand, there are clear differences in the amount of time participants in the different groups spent browsing ChemLab. Browsing patterns and use of the various cognitive media types also appear to differ across the experimental conditions. Details of these differences will be examined in the near future. Overall, it seems clear that the experimental manipulations did affect the usage of the ChemLab software, though it is not yet clear what the relationship is between usage patterns and post-test performance.

Computer Graph Theory

The Computer Graph Theory module taught students all about graph data structures and their use. It touched on topics such as connectivity, directed vs. undirected, completeness, and included related algorithms and data structures such as shortest path, minimum spanning tree, and searches.

Participants were 148 undergraduate Georgia Tech undergraduate students enrolled in an introductory computer programming course.

The Algonet2 software was installed over a network of personal computers spanning two undergraduate labs. The computers were IBM 486 compatibles running Windows 3.1 with 14" SVGA displays.

The students received a packet of written instructions and a problem to be solved requiring the application of graph theory. Students' interaction was logged to files for later analysis. After the students had completed the lab and shut down the Algonet2 program, they were asked to complete a post-lab questionnaire that asked them questions about their academic background, exposure to and usage of computers as well as their impressions about different parts of the Algonet2 system. A fourth source of data came from four students who volunteered to have their interactions with the system videotaped as well.

Interaction with the system was mouse-driven. The students clicked on buttons (e.g., back, quit, help, help-on-help), boxes in the topic tree, and lines of text in the question-asking interface.

The system contains groups of pages, each group focusing on one topic in graph theory.

Preliminary analyses of the data are just beginning.

Publications

None

Papers Submitted for Publication

None

Papers in Refereed Conference Proceedings

None

Paper Presentations

We will be presenting the preliminary findings of our work at the workshop we are co-sponsoring in New Mexico in February.

Upcoming Research

We plan to rerun the chemistry experiment in a more controlled setting and perhaps with more challenging problems. These changes will accomplish two things: first, the increased

problem difficulty might allow us to detect learning differences among the experimental groups; second, the more controlled setting will allow us to more closely monitor and shape learners' interactions with the system in order to determine whether the manipulations can affect learning. While this increased control will make it more difficult for us to determine learners' "natural" interactions with the system, the control is necessary in order to for us to determine whether the manipulations can affect learning. Additional work can then look at how easily and naturally learners' make use of various features and whether they like them

We also plan to do additional studies with the Algonet2 software that will match the manipulations done in chemistry. The importance of this approach is to allow us to demonstrate the generality of our findings and to see if the instructional approaches we are developing can be applied to multiple domains.